# CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

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# CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

## 8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducts to evaluate the economic impacts on individual consumers that would be required to comply with proposed energy conservation standards for walk-in coolers and freezers (walk-ins or WICF).

Appliance efficiency standards usually decrease operating costs and increase purchase costs for consumers. However, in this particular standard, a number of the walk-in efficiency improvements under consideration decrease both operating costs and purchase costs. This chapter describes the two metrics used in this analysis to determine the impact of standards on individual consumers:

- The life-cycle cost (LCC) is the total (discounted) consumer cost over the analysis period including purchase price, operating costs (including energy expenditures), and installation costs. LCC savings is the reduction in LCC that a consumer would benefit from if switching to more efficient equipment.
- The payback period (PBP) is the number of years it takes a customer to recover the generally higher purchase price of more energy-efficient equipment through the operating cost savings of using the more energy-efficient equipment. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

While the two metrics vary in their precise meaning, they share the same basic implication: the lower the value, the more financially attractive a piece of equipment is in the long run (at any given level of service). An efficiency improvement that is financially attractive will typically have a low LCC (or a high LCC savings) and low PBP. In rare cases, an efficiency improvement can be so financially advantageous that it exhibits a PBP that is less than zero, *i.e.*, the improvement reduces both operating costs and installed costs. As noted above, a number of the walk-in efficiency improvements considered in this chapter meet this exceptionally stringent criterion for financial benefit.

DOE is considering setting separate performance standards on the two different components of a walk-in, the envelope and the refrigeration system. But, because a walk-in cooler or freezer operates as a combined unit, DOE analyzed the life cycle cost and payback period of a walk-in as a whole. In this life cycle cost analysis, DOE analyzed pairs of envelopes and refrigeration systems equipment classes—*e.g.*, a small display cooler might be paired with a small dedicated indoor medium-temperature refrigeration system.

This chapter is laid out as follows. The remainder of sections 8.1 outlines the general approach for the LCC and PBP analyses and describes the inputs in broad strokes. Sections 8.2 and 8.3 discuss inputs to the LCC and PBP, respectively, in greater detail. Section 8.4 presents summary results for the LCC savings. Appendix 8A provides more detailed results for the LCC and PBP. Key variables and calculations are presented for each metric. DOE performs the calculations discussed here using a series of Microsoft Excel spreadsheets developed for this rulemaking. Stakeholders are invited to download and examine the spreadsheets available at www1.eere.energy.gov/buildings/appliance_standards/commercial/wicf.html. Appendix 8B will present details and instructions for using the spreadsheet.

### 8.1.1 General Approach for LCC and PBP Analyses

To conduct the LCC and PBP analyses, DOE first estimates all of the installed costs and annual operating costs for each possible combination of envelope and refrigeration system for representative equipment classes, both in the base case and at each possible combination of the efficiency levels used in the engineering analysis (preliminary technical support document [TSD] chapter 7). Because those efficiency levels are candidates for potential standards for the envelope and refrigeration system, DOE refers to them as candidate standard levels (CSLs) in the LCC and PBP analysis as well as the following chapters. With this information, the analyses can be conducted in the following manner:

- For the life cycle cost analysis, DOE discounts all annual operating costs across the expected lifetime of the unit, adds them together, and then adds that sum to the installed costs to find the LCC. Then, the LCC at each CSL is subtracted from the baseline LCC to find the LCC savings for that CSL.
- For the PBP analysis, DOE sums the operating costs across the expected lifetime of the unit and then divides that amount by that lifetime to produce an average operating cost per year at the baseline and at each CSL. Then, the operating cost per year at each CSL is subtracted from the baseline operating costs per year to find an operating cost savings per year. Similarly, DOE calculates the increase in installed costs per year. DOE then divides the installed cost increase by the annual operating cost savings to determine the PBP.

DOE typically uses the operating costs in the first year to calculate PBP. However, for the preliminary WICF analysis, DOE uses average operating costs instead for the following reason. Replacement costs for WICF equipment are significant in an average year because the refrigeration system and doors require replacement during the life cycle of a typical walk-in. Yet these costs are zero in the first year, before any equipment needs replacing. Since replacement costs are a subset of operating costs, a PBP calculation based on operating costs in the first year would produce a misleading result for this type of equipment. Section 8.2.3.3 describes replacement costs in more detail.

To calculate the installed costs for both the LCC and PBP analyses, DOE produces estimates of purchase costs of both the envelope and refrigeration system (including sales taxes and other markups), shipping costs, and installation costs. Those estimates are discussed further in section 8.2.2.

To calculate the operating costs, DOE produces estimates of electricity costs (based on annual electricity use and electricity prices), maintenance costs, and replacement costs. Repair costs were not included because DOE determined that most walk-in equipment failures are resolved through replacing rather than repairing the broken component. Those estimates are discussed further in section 8.2.3. Figure 8.1.1 depicts the relationships between the different of the LCC and PBP analysis. In this figure, the rectangular boxes indicate the inputs, the parallelograms indicate intermediate calculated values, and the diamond boxes indicate the analysis outputs (the LCC and PBP).

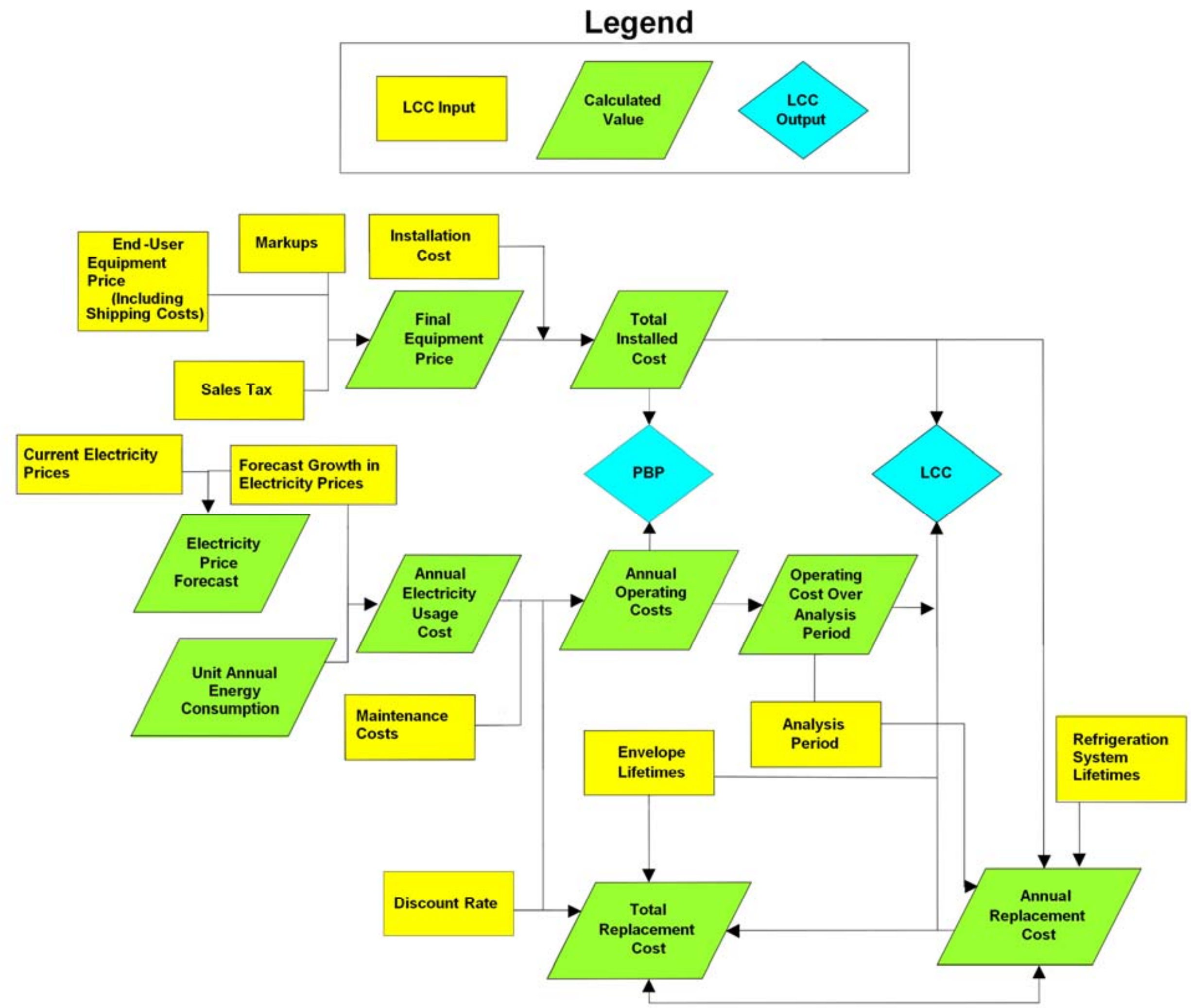


**Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP**

DOE is conducting the LCC and PBP analyses on the baseline equipment from the representative equipment classes identified in the market and technology assessment (preliminary TSD chapter 3). Because the energy consumption of a walk-in depends on both the envelope and the refrigeration system, it is not possible to analyze the energy costs—and the resulting LCC or PBP—of an envelope or refrigeration system in isolation. Accordingly, DOE analyzes the LCC and PBP of individual pairings of particular types of envelopes and refrigeration systems (equipment classes) in combination. Table 8.1.1 shows all pairings of equipment classes that DOE is evaluating in this analysis.

**Table 8.1.1 Equipment Classes Analyzed in the LCC and PBP Analyses**

| **Class/ Size Code** | Small Non-Display Cooler (SCS)* | Medium Non-Display Cooler (SCM) | Large Non-Display Cooler (SCL) | Small Display Cooler (DCS) | Medium Display Cooler (DCS) | Large Display Cooler (DCL) | Small Non-Display Freezer (SFS) | Medium Non-Display Freezer (SFM) | Large Non-Display Freezer (SFL) | Small Display Freezer (DFS) | Medium Display Freezer (DFM) | Large Display Freezer (DFL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Small Medium-Temperature Indoor Dedicated System | √ | | | | | | | | | | | |
| Large Medium-Temperature Indoor Dedicated System | | √ | √ | √ | √ | √ | | | | | | |
| Small Medium-Temperature Outdoor Dedicated System | √ | | | | | | | | | | | |
| Large Medium-Temperature Outdoor Dedicated System | | √ | √ | √ | √ | √ | | | | | | |
| Small Medium-Temperature Multiplex System | √ | | | | | | | | | | | |
| Large Medium-Temperature Multiplex System | | √ | √ | √ | √ | √ | | | | | | |
| Small Low Temperature Indoor Dedicated System | | | | | | | √ | | | | | |
| Large Low Temperature Indoor Dedicated System | | | | | | | | √ | √ | √ | √ | √ |
| Small Low Temperature Outdoor Dedicated System | | | | | | | √ | | | | | |
| Large Low Temperature Outdoor Dedicated System | | | | | | | | √ | √ | √ | √ | √ |
| Small Low Temperature Multiplex System | | | | | | | √ | | | | | |
| Large Low Temperature Multiplex System | | | | | | | | √ | √ | √ | √ | √ |

* Letter codes in parentheses are abbreviations.

### 8.1.2 Overview of LCC and PBP Inputs

As mentioned previously, the LCC represents the total consumer expense over the analysis period, including purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounts future operating costs to the time of purchase and sums them over the analysis period. The PBP represents the number of years it takes customers to recover the purchase price of more energy-efficient equipment through lower operating costs. The PBP is calculated as the change in first cost divided by the change in operating costs in per year.

DOE characterized all of the total cost inputs with single-point values for this preliminary LCC analysis, focusing on the average impacts to the nation. For the next stage of this analysis, DOE intends to also perform a Monte Carlo analysis that will characterize several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability across U.S. States (TSD appendix 8C).

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during operation of the walk-in, otherwise known as the operating costs. The primary inputs for establishing the LCC and PBP are shown in Table 8.1.2. Each row of the table also gives the chapter of the preliminary TSD, which provides more detailed information about this input.

**Table 8.1.2 Summary Information of Inputs for the Life-Cycle Cost and Payback Period Analyses**

| Factor | TSD Reference Section |
|---|---|
| **Total Installed Cost Primary Inputs** | |
| Manufacturer Selling Price | Chapters 5, 7 |
| Distributer Markup and Sales Tax | Chapter 7 |
| Installation Cost | Chapter 8 |
| **Operating Cost Primary Inputs** | |
| Annual Energy Consumed | Chapter 6 |
| Current Electricity Prices | Chapter 8 |
| Electricity Price Trends | Chapter 8 |
| Discount Rate | Chapter 8 |
| Walk-in Lifetime | Chapter 8 |

Sections 8.2 and 8.3 discuss the inputs of installed costs and operating costs that are depicted in this table.

## 8.2 LIFE-CYCLE COST INPUTS

### 8.2.1 Definition of Life Cycle Cost

LCC is the total customer cost over the life of a good, including total installed costs and operating costs. Future operating costs are discounted to the analysis start year (*e.g.*, 2015) and summed over the analysis period. The LCC is defined by the following equation:

$$LCC = IC + \sum_{t=1}^{N}\left(\frac{OC_t}{(1+r)^t}\right) \qquad \textbf{Eq. 8.1}$$

Where:

| | | |
|---|---|---|
| $LCC$ | = | life-cycle cost, |
| $IC$ | = | total installed cost, |
| $N$ | = | analysis period, |
| $\sum$ | = | sum over the analysis period, from year 1 to year $N$, |
| $OC$ | = | annual operating cost in year t, |
| $r$ | = | discount rate, and |
| $t$ | = | year for which operating cost is determined. |

DOE expresses all the costs in its LCC and PBP analyses in 2009$.

### 8.2.2 Total Installed Cost Inputs

The total installed cost of a walk-in to the customer is defined by the following equation:

$$IC = FEP_E \times FEP_R + INST \qquad \textbf{Eq. 8.2}$$

Where:

| | | |
|---|---|---|
| $FEP_E$ | = | envelope final equipment price (*i.e.*, customer price for the equipment only), |
| $FEP_R$ | = | refrigeration system final equipment price, and |
| $INST$ | = | installation cost or the customer price to install the equipment (*i.e.*, the cost for labor and materials). |

The final equipment price represents the average cost of a walk-in component (envelope or refrigeration system) before installation costs. DOE then applies installation costs where necessary to derive the total installed costs for use in the LCC. Thus, the total installed cost for a walk-in equals the final equipment price of each component plus the installation cost. The installation cost represents all costs required to install the walk-in except the final equipment price. The installation cost includes labor and overhead and is described below.

DOE calculates the final equipment cost for each walk-in component analyzed based on the following equation:

$$FEP = PRICE \times MU \times (1 + ST) \qquad \textbf{Eq. 8.3}$$

Where:

| | |
|---|---|
| *FEP* = | envelope or refrigeration system final equipment price, |
| *PRICE* = | envelope or refrigeration system manufacturer selling price (including shipping costs), |
| *MU* = | distribution channel markup, and |
| *ST* = | sales tax. |

DOE calculates the manufacturer selling price for both envelopes and refrigeration systems in the engineering analysis (preliminary TSD chapter 5). The markup represents DOE estimates of the additional costs to the consumer of obtaining WICF equipment through whatever distribution channel the consumer uses. The sales tax represents State and local sales taxes applied to the end-user equipment price. It is added to one to produce a multiplicative factor that increases the final equipment price. The markup analysis (preliminary TSD chapter 6) provides detail on the markup and sales tax.

#### 8.2.2.1 Manufacturer Selling Price

As noted above, the manufacturer selling price represents the average cost of a walk-in component (envelope or refrigeration system) to distributors before distributor markup, installation costs, and sale tax. It is described in the engineering analysis (preliminary TSD chapter 5).

#### 8.2.2.2 Installation Costs

This input represents the cost to the customers of installing the walk-in. The installation cost represents all costs required to install the system but does not include the end-user equipment price. The installation cost includes labor and overhead. Thus, the total installed cost equals the end-user equipment price including sales tax plus the installation cost.

WICF equipment and components are generally installed from two different vendors *i.e.*, one supplying the envelope components and a different vendor supplying the components of the refrigeration system. Generally, the enclosures are field installed from the insulated panels, doors, and other components supplied by the WICF envelope manufacturer by a specialized crew (carpenters). A different crew installs the refrigeration system components and electrical components associated with the envelope, such as lights and air curtains. For some smaller systems, the entire assembly comprising both the enclosure and the refrigeration system are sometimes factory assembled and mounted on a trailer for final delivery to the customer site. DOE estimated the total installation costs for the WICF systems by aggregating separate installation costs for the envelope, the unit cooler in the enclosure, and the condensing unit. For the systems coupled with multiplex systems, DOE added only the first two cost elements because the multiplex condensing systems are usually shared with other equipment. For estimating the installation costs of the WICF subsystems, DOE used installation cost data for the specific subsystems from an industry publication, *RSMeans Mechanical Cost Data*.[1] The installation cost data for different sizes or capacities of a specific piece of equipment were pooled, and a linear relationship was sought between the installation cost and the size/capacity. However, DOE noticed that using a single pool of data and using a linear relationship across the entire range of sizes could lead to considerable estimation errors around range extremities. Consequently, DOE partitioned the whole range into smaller sub-ranges over which a linear relationship could be established and used with smaller errors of estimates. $R^2$ parameters of the regression analysis were used as an indicator of the goodness-of-fit.

***Envelopes***

In the reference version of the *RSMeans Mechanical Cost Data* handbook, the labor cost for installing the WICF system (Division number 13 21 26.50), including doors and floors but not including the partitions within the enclosure and refrigeration system, are reported for four different sizes of enclosures. The smallest size in the set of four is for a WICF system of 6 ft × 6 ft outside dimension and was considered unrepresentative for the set of WICF enclosures selected for analysis.  For the other three WICF enclosures, the bare labor cost reported for the smallest enclosure of 6 ft × 6 ft outside dimensions was \$7.80 per sft. For both the intermediate-sized WICF enclosure of 12 ft × 14 ft and the largest-sized 12 ft × 20 ft outside dimensions, the bare labor cost reported was \$5.85 per sft. Consequently, DOE used only two per sft unit installation cost rates in estimating the installation cost for the WICF enclosures. For the enclosures with an area less than 168 sft, DOE used the higher rate of \$7.80 per sft. For enclosures having areas larger than the threshold value, the lower rate of \$5.85 was used. The bare labor cost was multiplied by the installing contractors overhead and profit percentage (55.10 percent) reported in the referenced handbook for this category of labor (carpenters).

***Unit Coolers***

For estimating the installation cost of the unit coolers, DOE extracted the installation labor hours data for the unit coolers of different capacities tabulated under classification 23 76 16 from the *RSMeans* handbook. Though the installation cost of a specific unit cooler is not entirely determined by its capacity (Btu/ hr), other parameters were ignored for reasons of simplicity. A unit cooler with the same physical dimension but having evaporator tubes with different fin densities (fpi) may have nearly the same installation costs, but significantly different capacities.

DOE obtained plots of the installation labor hours against the capacities of the unit coolers in different capacity ranges. DOE assumed that using pooled data for unit coolers with somewhat differing specifications resulted in installation cost plots for generic unit coolers.  The plots obtained from the pooled data are shown in Figure 8.2.1, Figure 8.2.2, and Figure 8.2.3.

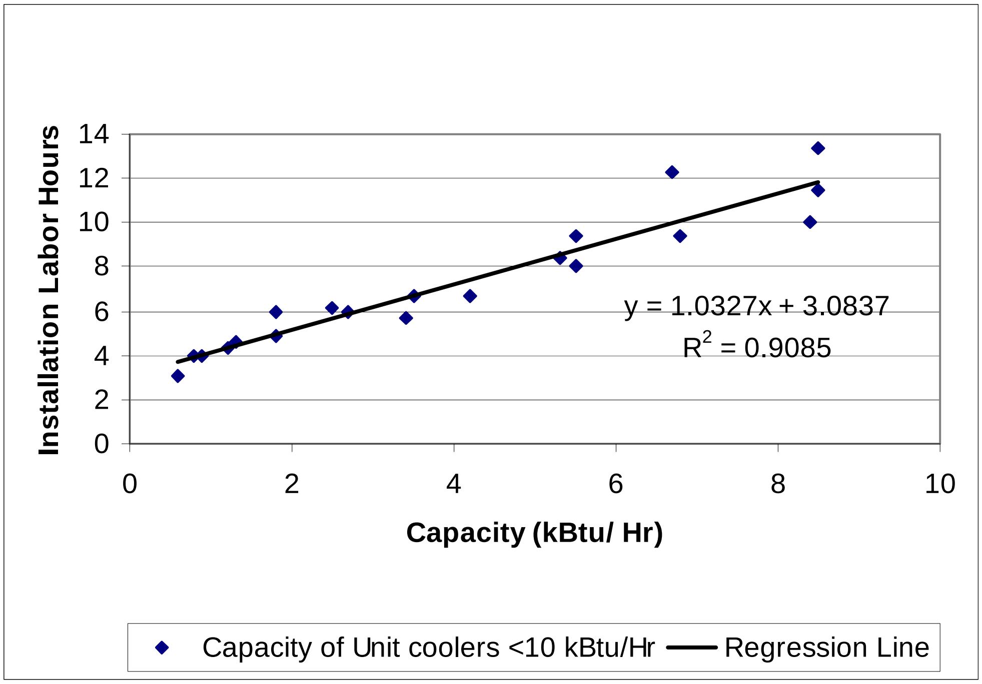


**Figure 8.2.1 Installation Labor Hours for Small Unit Coolers**

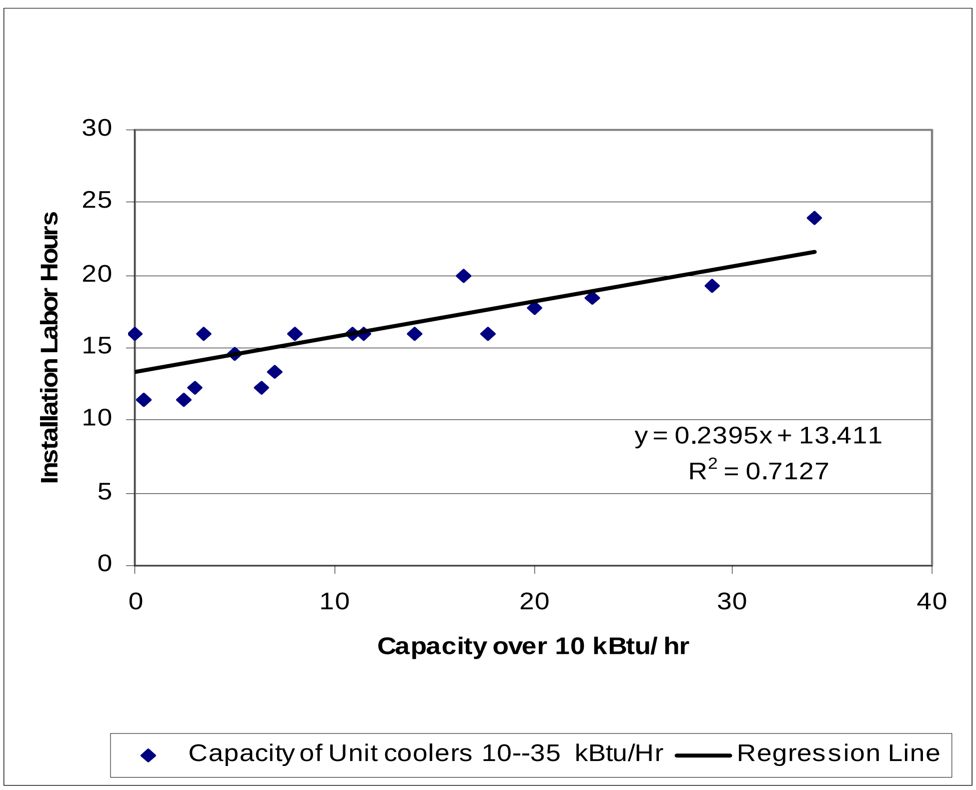


**Figure 8.2.2 Installation Labor Hours for Medium Unit Coolers**

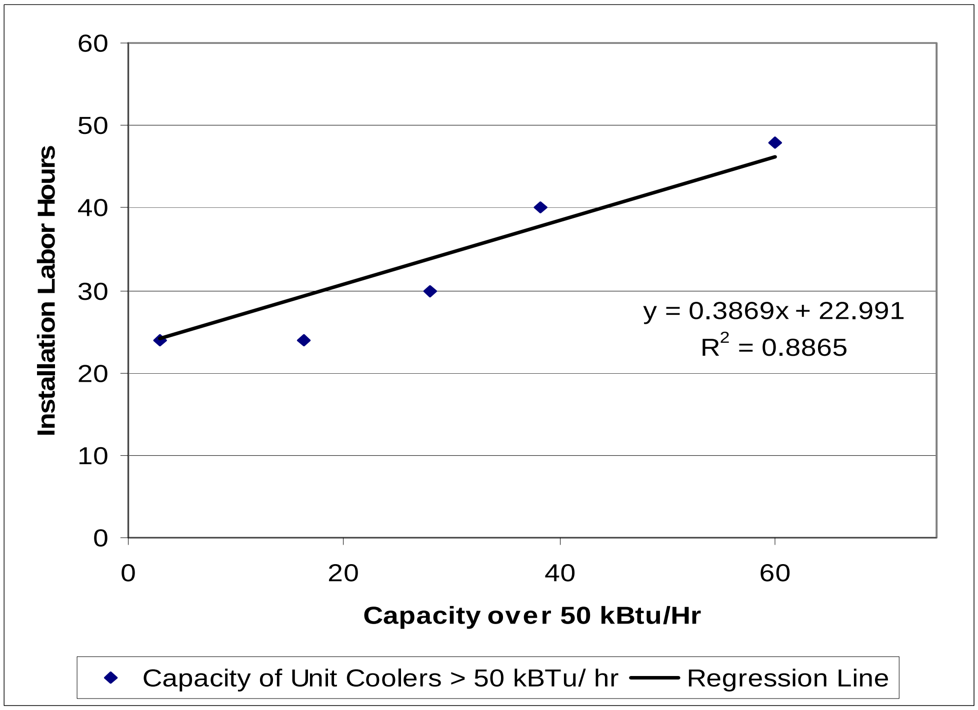


**Figure 8.2.3 Installation Labor Hours for Large Unit Coolers**

From the installation labor hours against capacity plots for the unit coolers, regression lines were fitted, and the intercept and the slopes of the line and $R^2$ values were obtained. For maintaining continuity of the intermediate end points of the plots, the terminal value obtained from the plot for the previous range was forced as an intercept for the plot for the next higher range. This resulted in somewhat lower $R^2$ values in the plots for the medium and high capacity unit coolers. The slopes and the intercepts were directly converted to the corresponding intercept and slope for the installation cost regression line using a labor hourly rate multiplier of US$66.67/hour obtained from the *RSMeans* handbook[1] (p. 629). The labor hour rate includes the bare labor costs, overheads, and profit. The results of this analysis are shown in Table 8.2.1 and have been used to estimate the installation costs of unit coolers used in this LCC analysis.

**Table 8.2.1 Slope and Intercept Values Used for Estimation of Installation Costs of Unit Coolers**

| Unit cooler Capacity Range Btu /Hr | Labor hour Plot | | Installation Cost ($) Plot | |
|---|---|---|---|---|
| | Slope | Intercept | Slope | Intercept |
| < 10,000 | 1.0327 | 3.0837 | $68.85 | $205.59 |
| <50000 | 0.2395 | 11.016 | $15.97 | $734.44 |
| >50,000 | 0.3869 | 3.646 | $25.79 | $243.08 |

### *Condensing Units*

To estimate the installation cost for the condensing units, labor cost data for installing the packaged compressor and condensing units (Division number 23 62 13.10) were extracted from the reference version of the *RSMeans Mechanical Cost Data* handbook. The plots for the labor cost for installation and the capacity of the condensing unit in kBtu/hr for smaller sized units with capacity less than 5 tons (60 kBtu/ hr) are shown in Figure 8.2.4. The intercept of the slope of the regression line in the plot is used for estimating the labor cost of installing the condensing units with a capacity less than 5 tons.

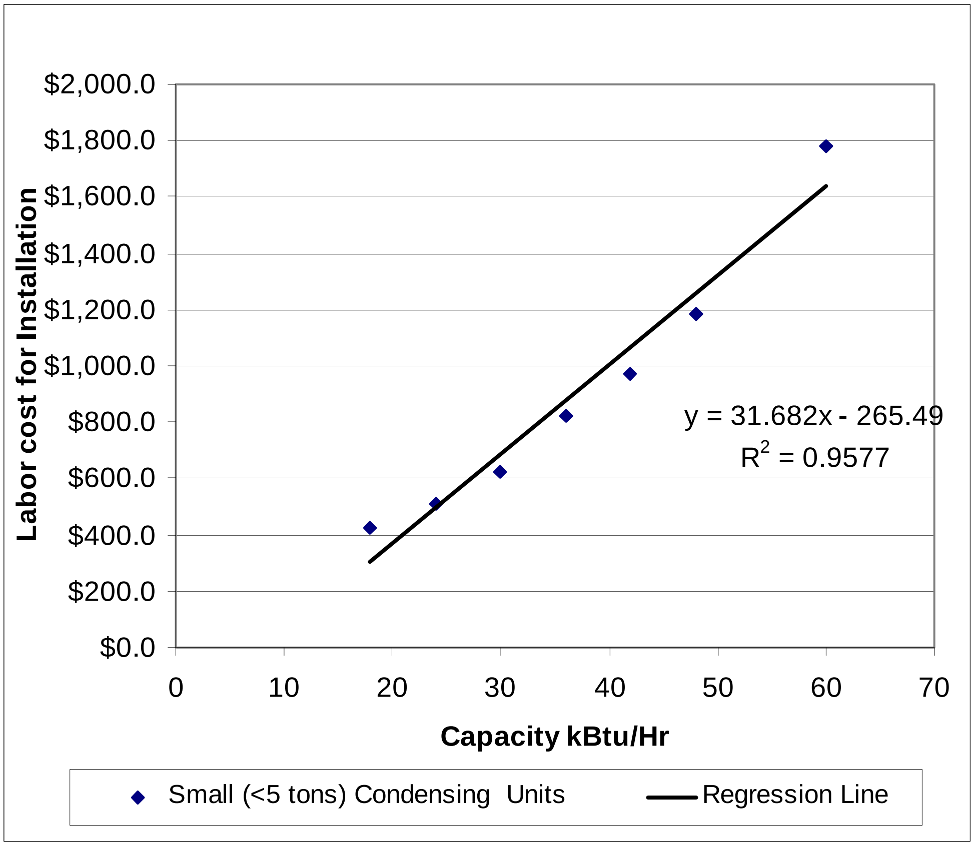


**Figure 8.2.4 Installation Cost in Dollars for Small (Under 5 Tons) Condensing Units**

For the larger sized condensing units, the *RSMeans* reference handbook reports installation costs over a range of sizes, the maximum size being 100 tons. The regression plot of the installation labor cost for the larger capacity range of condensing units is forced to pass through the end point of the regression line for the units of smaller capacity to avoid discontinuity. The plot of the labor cost for installation against the differential capacity over 12,000 kBtu/ hours is presented in Figure 8.2.5.

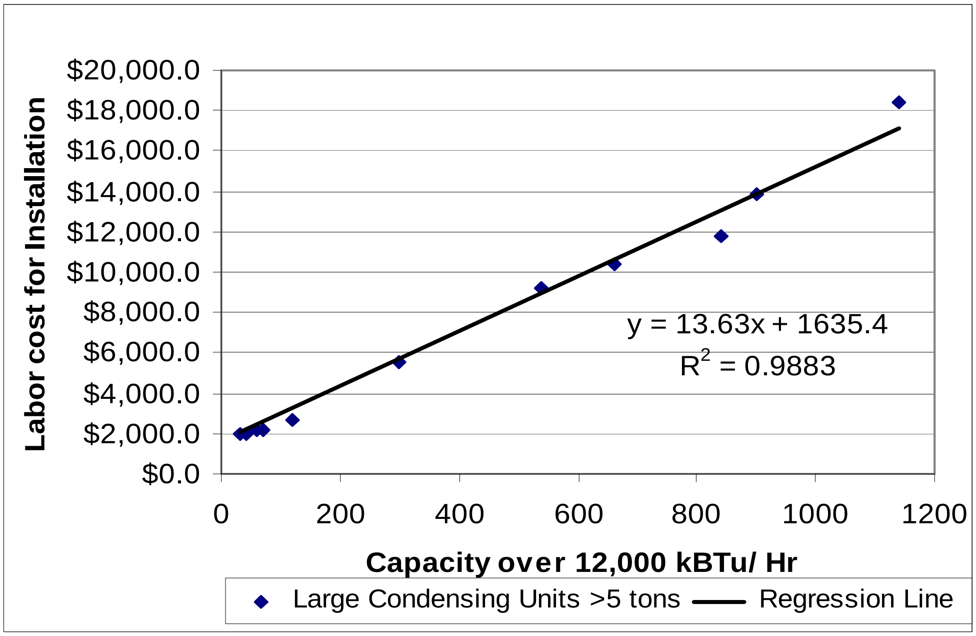


**Figure 8.2.5 Installation Cost in Dollars for Large (Over 5 Tons) Condensing Units**

The slope and the intercept values used in the two ranges for projecting the labor cost of installing the condensing units of different sizes are shown in Table 8.2.3. The difference in the intercept values in the plot for the large-sized units and the table value is due to the difference in the definition of the x-axis variables.

**Table 8.2.2 Slope and Intercept Values Used for Estimation of Installation Costs of Refrigeration Systems**

| Capacity in kBtu/Hr | Slope | Intercept |
|---|---|---|
| < 60 | 31.682 | -265.49 |
| >60 | 13.63 | 817.6 |

### 8.2.2.3 Distributor Markup and Sales Tax

As noted above, DOE calculates the end-user equipment price by multiplying the manufacturer selling price by a  distributor markup to determine the final equipment price. This markup includes both a distributor markup component and a sales tax component.

Different markups are calculated for different equipment classes based on their of distribution channels. Specifically, the markups analysis distinguishes between remote condensing and self-contained equipment refrigeration systems.

For the preliminary LCC and PBP analyses, DOE calculated and used a national average sales tax. For the Monte Carlo analysis in the next round of analysis (appendix 8A of the TSD), DOE intends to use State-specific sales taxes.

DOE then applies the sales tax to complete the conversion of the end-user equipment price to the final equipment price. The markups analysis (chapter 7 of the preliminary TSD) describes the distributor markup and sales tax markup in detail.

### 8.2.3 Operating Cost Inputs

The operating cost represents the costs incurred in operating the walk-in. This includes energy costs, maintenance costs, and replacement costs. Table 8.2.3 lists the inputs for operating costs. The analysis period, discount rate, and effective date of the amended standard are required for determining the operating cost and for establishing the operating cost present value. A primary driver of the operating costs is the electricity consumption for the baseline, and other CSLs are examined to enable comparison of standard operating costs.

**Table 8.2.3 Inputs for Operating Costs**

| |
|---|
| Annual Electricity Consumption (kWh) |
| Current Electricity Prices ($/kWh) |
| Electricity Price Trend |
| Equipment Lifetimes (years) |
| Discount Rate (%) |
| Replacement Costs ($/year) |

Electricity prices used in the analysis are the price per kilowatt-hour in cents or dollars (*e.g.*, $/kWh) paid by each customer for electricity. DOE uses electricity price trends to forecast electricity prices for future year analysis. These trends with the electricity price and annual energy consumption are used to calculate the energy cost in each year. DOE defines energy cost by the following equation:

$$\begin{aligned} OC &= E_{cons} \times EP \times EPT \\ &= (PWR \times OH) \times EP \times EPT \end{aligned} \qquad \textbf{Eq. 8.4}$$

Where:

$OC$ = operating costs,
$E_{cons}$ = annual energy consumed,
$EP$ = electricity price,
$EPT$ = electricity price trend factor relative to 2007,
$PWR$ = power rating (rate of energy use, measured in watts), and
$OH$ = annual operating hours.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs.

#### 8.2.3.1 Energy Costs

The annual energy costs for each WICF unit is an important input to the LCC and PBP analyses. Since walk-ins are almost exclusively powered by electricity, DOE defined energy costs in any given year as the electricity use per year multiplied by the electricity price in that year.

DOE calculates annual walk-in electricity consumption as described in the energy use characterization (chapter 7 of the preliminary TSD).

DOE combines two different data sources to estimate future electricity prices. The current electricity prices are taken from U.S. Energy Information Administration (EIA) Form 861 data. [2] DOE then grows the current price estimates by the long-term electricity price growth rates used in the most recent available version of the National Energy Modeling System (NEMS), the updated (April 2009) version of the Annual Energy Outlook 2009 (AEO 2009-B).[3] In this way, the latest available short-term prices can be combined with the longer-term growth projections. The method is described below.

***Current Electricity Prices***

As noted above, DOE develops all electricity price inputs using monthly data from EIA Form 861. DOE uses the average price per kilowatt-hour (*i.e.*, $/kWh) paid by customers. DOE determines electricity prices using national average commercial and industrial electricity prices for the sample calculation, weighted according to the share of walk-ins estimated to be in the commercial and industrial sectors. Those weights are detailed in the shipments analysis (preliminary TSD chapter 9). For the Monte Carlo distribution, DOE will use average commercial and industrial values by State for the current electricity price.

The EIA Form 861 data are published annually and include annual electricity sales in kilowatt-hours; revenues from electricity sales; and number of consumers for the commercial and industrial sectors for every State. DOE calculates average electricity prices for each State by dividing the total commercial or industrial revenues from the EIA Form 861 data by total commercial or industrial sales from the same source.

The calculation uses the most recent 12 months of available EIA data at the time the analysis was conducted, from September 2008 through August 2009. Because DOE conducted the LCC and PBP analyses in 2009$, it needed to convert all electricity prices into 2009$. To perform the necessary monetary conversion, DOE uses the consumer price index (CPI) to convert the 2008 electricity prices from 2008$ to 2009$.

***Electricity Price Trend***

The electricity price trend projects the future cost of electricity to 2045. DOE normalizes the *AEO2009-B* scenarios to the 2008-2009 electricity prices and then uses that electricity price factor to scale up the 2008-2009 electricity prices over time through 2030. The AEO 2009-B price projections do not continue past 2030, so for the years 2031-2045, DOE flatlines the electricity price projections. Figure 8.2.6 shows the commercial and industrial electricity price trends, respectively, based on the two *AEO2009-B* projections. Both sectors are forecast to experience a fall in electricity prices (measured in real dollars) before the analysis period, but rising electricity prices during the analysis period. The *AEO2009-B* provides only reference case electricity prices.

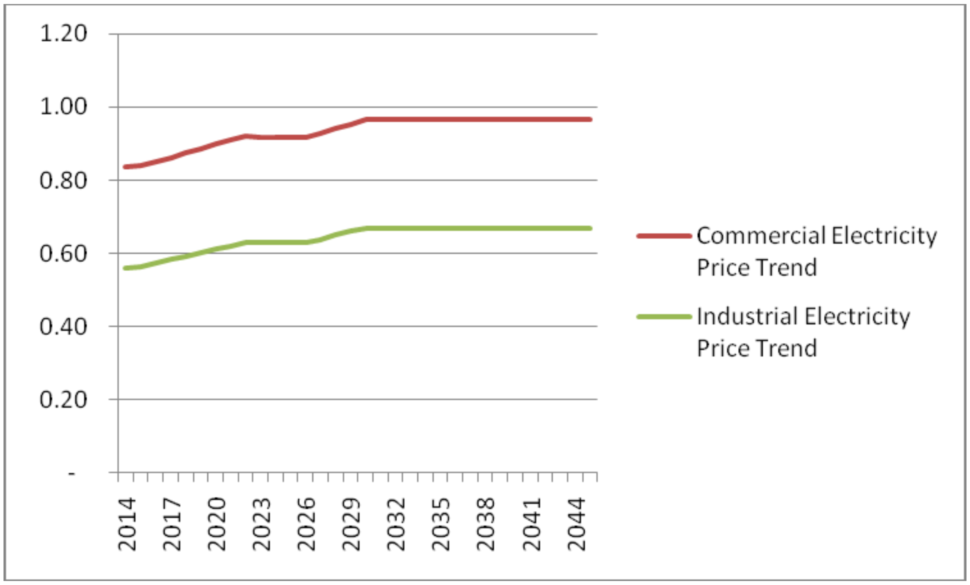


**Figure 8.2.6 Electricity Price Trend Projections by Sector**

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in both the LCC spreadsheets and the LCC results tables in this chapter and in the detailed results appendix (appendix 8A).

#### 8.2.3.2 Maintenance Costs

The maintenance cost is the cost to the consumer of maintaining equipment operation. In this analysis, DOE considered only the costs associated with general maintenance (*e.g.*, checking and maintaining refrigerant charge levels, checking settings, cleaning heat exchanger coils).

DOE took annualized maintenance costs for WICF equipment (Classification 1095) from data in *RSMeans Facilities Maintenance & Repair Cost Data.*[4] *RSMeans* provides estimates on the labor hours, labor rates, and materials required to maintain WICF equipment.

The *RSMeans* cost data covered both display and non-display type WICF equipment with external condensers only and ranged from $158 to $239 on annualized basis. Equipment sizes were not indicated. DOE assumed that the maintenance costs do not vary with the size and also that the cost is the same for equipment with internal and external condensing units. Further, DOE decided to use constant preventative maintenance costs independent of equipment efficiency.

In addition to the preventative maintenance, DOE considered replacements of lamps and ballasts and other lighting maintenance activities as an essential maintenance activity for WICF equipment. Different sizes of WICF equipment in different equipment classes have different numbers of lamps (and ballasts), and several efficiency options that DOE considered in its design option for engineering analysis involved changes to the lighting configuration (lamp, ballast, or use of light emitting diode (LED) lighting systems). Because the lighting configurations can vary by efficiency level, DOE estimated the relative maintenance costs for lighting for each analyzed equipment type. DOE's methodology was to estimate the frequency of failure and replacement of individual lighting components, to estimate the cost of replacement in the field, and to develop an annualized maintenance cost based on the aggregate lighting maintenance costs (in 2009$) over the estimated life of the equipment .

The number of total lifetime replacements for particular types of lamps was estimated as follows:

- Fluorescent lamps (T8 and compact fluorescent lamp [CFL]) would be replaced eight times in a preventative fashion over the entire life of the WICF equipment.
- LED lamps would be replaced three times over the WICF equipment lifetime based on a typical fixture life of 50,000 hours (GE 2007).[5]

However, some of the lamp replacements coincide with the display door replacements, and since the replacement of doors inclusive of the lamps has been separately considered, only non-coincidental replacements were considered. Thus, effectively no separate replacements were considered either for the fluorescent lamp ballasts or the LED lamps.

DOE based cost estimates for fluorescent lamps (CFL and T8) on a review of the original equipment manufacturer (OEM) costs used in the engineering analysis and *RSMeans* estimates. The final approach taken was to estimate the costs of field replacement using labor cost hours from *RSMeans Electrical Cost Data*[6] for typical lamp or ballast replacement for other lighting fixtures, and to provide a 150-percent multiplier on OEM costs for lamps (provided in the engineering analysis spreadsheets) to reflect retail pricing.

Table 8.2.4 and Table 8.2.5 show the annualized lighting maintenance costs for each efficiency level addressed in the LCC analysis.

**Table 8.2.4 Annualized Maintenance Costs for Each Efficiency Level from Baseline to Efficiency Level 7 for Life-Cycle Cost Analysis (2009$)**

| | Efficiency levels | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **WICF Class/ Size** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **SCS** | $2,462 | $2,462 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SCM** | $2,462 | $2,462 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SCL** | $2,647 | $2,647 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 |
| **DCS** | $3,786 | $3,786 | $3,786 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 |
| **DCM** | $4,559 | $4,559 | $4,559 | $4,559 | $3,270 | $3,270 | $3,270 | $3,270 |
| **DCL** | $9,975 | $9,975 | $9,975 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 |
| **SFS** | $2,462 | $2,462 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SFM** | $2,462 | $2,462 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SFL** | $2,647 | $2,647 | $2,647 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 |
| **DFS** | $4,101 | $4,101 | $4,101 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 |
| **DFM** | $4,745 | $4,745 | $4,745 | $4,745 | $3,585 | $3,585 | $3,585 | $3,585 |
| **DFL** | $10,290 | $10,290 | $10,290 | $10,290 | $3,585 | $3,585 | $3,585 | $3,585 |

**Table 8.2.5 Annualized Maintenance Costs for Each Efficiency Level from Efficiency Levels 8-15 for Life-Cycle Cost Analysis (2009$)**

| | Efficiency Levels | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **WICF Class/ Size** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **SCS** | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SCM** | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SCL** | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 |
| **DCS** | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 |
| **DCM** | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 |
| **DCL** | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 | $3,270 |
| **SFS** | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SFM** | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 | $2,670 |
| **SFL** | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 | $3,269 |
| **DFS** | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 |
| **DFM** | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 |
| **DFL** | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 | $3,585 |

#### 8.2.3.3 Replacement Costs and Equipment Lifetime

Equipment lifetime is an important input to the LCC analysis in two different ways. One way is that the operating costs must be summed across each year in the lifetime of the equipment. The longer the lifetime, the more important annual operating cost savings become relative to installing cost increase. For a detailed explanation on how DOE derives its estimates of WICF equipment lifetimes, see the shipments analysis (preliminary TSD chapter 9).

The other way in which equipment lifetimes are important to the LCC analysis is that replacement costs are based on the relationship between the equipment lifetimes of the different walk-in components. This works as follows. Envelopes and refrigeration systems are both essential components of a single walk-in. Yet, because refrigeration system lifetimes are typically shorter than envelope lifetimes, DOE must consider whether the lifetime of a walk-in refers to the refrigeration system or the envelope. Because an envelope is typically longer-lived than a refrigeration system, keeping an envelope functioning for its normal lifetime frequently requires replacing its associated refrigeration system at least one time. Therefore, DOE is electing to define the lifetime of a walk-in as equal to the lifetime of its envelope and to treat any necessary refrigeration system replacements in that time period as replacement costs that feed into the operating costs.

Replacement costs are also included for envelope doors, which frequently have to be replaced over the lifetime of a walk-in. Based on manufacturer interviews, DOE estimates that envelope doors typically last 5 years on average.

Each year in which a refrigeration system or door reaches the end of its life, a replacement component is assumed to be purchased and installed at the beginning of that year. This component is assumed to cost the same as a new refrigeration system or door, including all shipping, installation, and other costs. The costs of those doors are derived in the engineering analysis (preliminary TSD chapter 5). During years in which replacement is necessary, DOE based the replacement costs on the total installed cost inputs, as seen in the following equation:

$$RC = FEP_L \qquad \textbf{Eq. 8.5}$$

Where:

| | | |
|---|---|---|
| $RC$ | = | replacement cost, and |
| $FEP$ | = | final equipment price (price for the equipment only). |

For the years when no replacement is necessary, the replacement costs are set to zero. For the LCC and PBP analyses, the analysis period corresponds with the envelope lifetime; for this reason, envelope replacement is not considered, and only refrigeration system and door price and labor costs are included in the calculation of total installed costs.

#### 8.2.3.4 Discount Rate

A discount rate is a rate at which future expenditures are discounted to establish their present value. The greater a discount rate used in an analysis, the less that future expenditures will be valued compared to current expenditures. Different actors in a market frequently apply different discount rates to future expenditures, *e.g.*, discount rates in the residential sector are typically not the same as commercial sector discount rates. For the WICF LCC analysis, DOE intends to use discount rates that are appropriate for each type of owner of WICF equipment. As detailed in the shipments analysis (preliminary TSD chapter 9), one way to classify WICF owners is by building or commercial establishment type—grocery stores, convenience stores, food service establishments, dairy farms, or “other.”

However, at the time of this preliminary analysis, DOE does not have sufficient information to calibrate these relationships precisely. Therefore, for the preliminary analysis, DOE bases its discount rates on the rates used in the 2009 “Commercial Refrigeration Equipment Final Rule” (72 FR 1092)[7] rather than producing new estimates specifically for walk-ins. This rule was used because the consumer base for commercial refrigeration equipment is the most similar of previous final rules to that for walk-ins, so the average discount rate for consumers of commercial refrigeration equipment is likely very similar to the average discount rate for consumers that operate walk-in coolers and freezers. DOE intends to revisit the issue of walk-in discount rates for the next stage of analysis.

The average after-tax discount rates used in 72 FR 1092 were 5.00 percent for large grocery stores, which DOE uses as an estimate of grocery store discount rates for the WICF preliminary analysis; 7.50 percent for convenience stores, which DOE uses for convenience store discount rates for this analysis; and 5.24 percent for multi-line retailers. For food sales establishments, dairy farms, and “other” WICF categories, DOE uses the average of these three discount rates, or 5.91 percent.

The basis for the discount rate estimates used in 72 FR 1092 was DOE estimates of the cost of capital for companies that purchase commercial refrigeration equipment. The cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the company of equity and debt financing. As explained in the CRE Final Rule, DOE estimated the cost of equity financing by using the Capital Asset Pricing Model (CAPM). The CAPM, which is among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a company.

### 8.2.4 Analysis Period and Effective Date of Standard

The effective date is the date when a standard becomes operative (*i.e.*, the date by which walk-in manufacturers must manufacture only equipment that complies with a standard). DOE's publication of a final rule in this standards rulemaking is scheduled for completion by January 1, 2012. The effective date of any energy conservation standards for these walk-ins must be at least 3 years after the final rule is published (42 U.S.C. 6295(g)(4)(C)), which will be January, 2015. DOE calculates the LCCs for all consumers as if each would purchase new equipment in the year the standard takes effect. However, DOE bases the cost of the equipment on the most recent available data; all dollar values are expressed in 2009$.

## 8.3 PAYBACK PERIOD INPUTS

### 8.3.1 Definition

The PBP is the amount of time it takes the consumer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (*i.e.*, from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" PBP because it does not take into account changes in operating cost over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent.

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC} \qquad \textbf{Eq. 8.6}$$

Where:

$PBP$ = payback period,
$\Delta IC$ = difference in the total installed cost between the more efficacious standard level; equipment (CSL 1, 2, etc.) and baseline (CSL 0) equipment, and
$\Delta OC$ = difference in annual operating costs.

PBPs are expressed in years. PBPs greater than the life of the equipment mean that the increased total installed cost of the more efficacious equipment is not recovered in reduced operating costs over its lifetime. Because all walk-in designs in the LCC and PBP analyses save energy and thus yield a positive $\Delta OC$, PBPs that are negative indicate that the total installed cost of the equipment that meets the more efficacious CSL is less than that of the baseline.

### 8.3.2 Rebuttable Presumption Payback Period

Section 325(o)(2)(B)(iii) of the Energy Policy and Conservation Act (EPCA) establishes a rebuttable presumption that an amended standard for walk-ins is economically justified if the Secretary finds that "the additional cost to the consumer of purchasing a product complying with an energy conservation standard level will be less than three times the value of the energy savings during the first year that the consumer will receive as a result of the standard, as calculated under the applicable test procedure" (42 U.S.C. 6295(o)(2)(B)(iii)). This rebuttable presumption test is an alternative path to establishing an economic justification compared to consideration of the seven factors set forth in 42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII).

Because DOE calculates PBPs in a methodology consistent with the rebuttable presumption test in the LCC and PBP analyses, DOE is not performing a stand-alone rebuttable presumption analysis because it is already embodied in the LCC and PBP analyses. Because calculations of energy savings in the LCC are based on real-world conditions, DOE will also rely on standard PBPs for this rulemaking.

### 8.3.3 Inputs

The data inputs to PBP are the total installed cost of the equipment to the customer for each CSL and the annual (first year) operating costs for each CSL. The inputs to the total installed cost are the final equipment price and the installation cost. The inputs to the operating costs are the walk-in input power rating, annual operating hours, and electricity cost. The PBP uses the same inputs as the LCC calculation described in section 8.2, except that electricity price trends are not required. Since the PBP is a "simple" (undiscounted) PBP, the required electricity cost is only for the year in which an amended energy conservation standard is to take effect (*e.g.*, 2014). The electricity price DOE uses in the PBP calculation for electricity cost is the price projected for 2014, expressed in 2009$, but not discounted to 2009. DOE does not use discount rates in the PBP calculation.

## 8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

As stated earlier, DOE conducts a series of LCC calculations for each baseline walk-in. Key inputs include the engineering analysis (preliminary TSD chapter 5), historical electricity prices from EAI File 861, electricity price projections from the *AEO2009*–B reference case, and an analysis period of 31 years.

Appendix 8A presents detailed LCC savings results for each combination of envelope and refrigeration system equipment classes that DOE considers. The LCC savings is the difference between the LCC of baseline equipment and equipment of any given combination of envelope and refrigeration system CSLs. When a standard results in positive LCC savings, this indicates that the LCC of the standards-compliant system is less than the LCC of the baseline system, and the consumer enjoys a financial benefit of the amount of the LCC savings. When a standard results in negative LCC savings, each WICF consumer would suffer a net financial loss of this amount were the standard to be set at that level.

### 8.4.1 LCC Savings Summary Results

This section presents summary LCC savings results. Table 8.4.1 summarizes the CSLs for envelopes and dedicated refrigeration systems that result in maximum LCC savings. For each envelope and refrigeration system pair, the cell shows the maximum LCC savings and the efficiency level of envelope and refrigeration. For example, the table shows that LCC savings for a large display freezer using a large multiplex refrigeration system are $146,800 per year and that this is achieved with a CSL 4 envelope and a CSL 2 refrigeration system.

The highest LCC savings typically occur when the efficiency levels of the envelope and refrigeration systems are at least somewhat similar; *e.g.*, a very efficient envelope and a very inefficient refrigeration system will likely not pair as an LCC-maximizing system. However, in many cases, the LCC is maximized at the highest possible efficiency level for the refrigeration system, but not for the envelope.

**Table 8.4.1 Summary of Maximum LCC Savings for All Matched Pairs of WICF Envelopes and Refrigeration Systems**

| Envelope | Maximum LCC Savings ($) and Matched Efficiency Levels for Envelope and Refrigeration Unit (a,b) | | | | | |
|---|---|---|---|---|---|---|
| | Refrigeration System* | | | | | |
| | Dedicated Indoor Small | Dedicated Indoor Large | Dedicated Outdoor Small | Dedicated Outdoor Large | Multiplex System Small | Multiplex system Large |
| Non-Display Cooler Small | $7,335 | - | $6,411 | - | $2,702 | - |
| | 5,6 | | 3,7 | | 3,2 | |
| Non-Display Cooler Medium | - | $13,720 | - | $14,019 | - | $5,288 |
| | | 5,6 | | 4,6 | | 1,3 |
| Non-Display Cooler Large | - | $28,369 | - | $30,808 | - | $10,393 |
| | | 1,6 | | 1,7 | | 1,3 |
| Display Cooler Small | - | $41,865 | - | $41,130 | - | $18,486 |
| | | 5,6 | | 5,7 | | 4,3 |
| Display Cooler Medium | - | $98,912 | - | $96,740 | - | $44,749 |
| | | 6,6 | | 6,7 | | 5,3 |
| Display Cooler Large | - | $552,429 | - | $546,793 | - | $242,378 |
| | | 6,6 | | 6,8 | | 6,3 |
| Non-Display Freezer Small | $27,867 | - | $26,124 | - | $11,071 | - |
| | 10,6 | | 10,7 | | 7,2 | |
| Non-Display Freezer Medium | - | $54,842 | - | $50,572 | - | $20,718 |
| | | 10,8 | | 10,9 | | 6,2 |
| Non-Display Freezer Large | - | $102,693 | - | $95,557 | - | $39,312 |
| | | 10,8 | | 10,9 | | 5,2 |
| Display Freezer Small | - | $53,548 | - | $50,779 | - | $19,658 |
| | | 10,6 | | 3,7 | | 3,2 |
| Display Freezer Medium | - | $108,341 | - | $104,054 | - | $40,191 |
| | | 11,7 | | 4,7 | | 4,2 |
| Display Freezer Large | - | $479,751 | - | $469,115 | - | $146,800 |
| | | 10,7 | | 4,9 | | 4,2 |

*Refrigeration system is matched to the envelope temperature regime. For example, a small non-display cooler will have a medium-temperature refrigeration system while a small non-display freezer will have a low-temperature refrigeration system.

### 8.4.2 PBP Results

Detailed PBP results are presented in appendix 8A. However, DOE does not present summary PBP results in the same manner as LCC savings results because the concept of PBP is less well suited to summarization. There is no appropriate equivalent to the metric used in Table 8.4.1. For example, the maximum payback period for all matched pairs of WICF envelopes and refrigeration systems is not a useful metric because it is not desirable to seek the maximum possible payback period. Presenting the optimal (minimum) payback periods and associated CSLs would also not be useful because the minimum payback period always occurs at the minimum possible CSL by definition. As noted in the engineering analysis (preliminary TSD chapter 5), the CSLs or efficiency levels are designed to consist of design options laid out in ascending order of payback period.

A key result of the WICF PBP analysis for is that the available design options present an unusually large number of negative PBP options. The concept of a payback period is typically used to compare the relative benefits of low initial purchase costs against the benefits of low operating costs over time. However, many of the candidate standard levels considered in this particular analysis do not face this situation. Rather, DOE identifies numerous possible efficiency improvements in WICF equipment that would both decrease purchase costs and decrease operating costs for the consumer, presenting no such tradeoff. Therefore, for many of the candidate standard levels in this rulemaking, the PBP is a negative number. The concepts of PBP and rebuttable PBP were not designed to distinguish well between different negative values, which have multiple possible interpretations. If two different efficiency options are both negative, it does not necessarily hold that the option with the lower PBP is more financially attractive. However, it is safe to say that *any* negative value for a PBP or rebuttable PBP indicates an uncommonly attractive financial option because it indicates a choice that saves money at a later date for less than zero cost. As noted above, detailed PBP results are presented in appendix 8A.

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